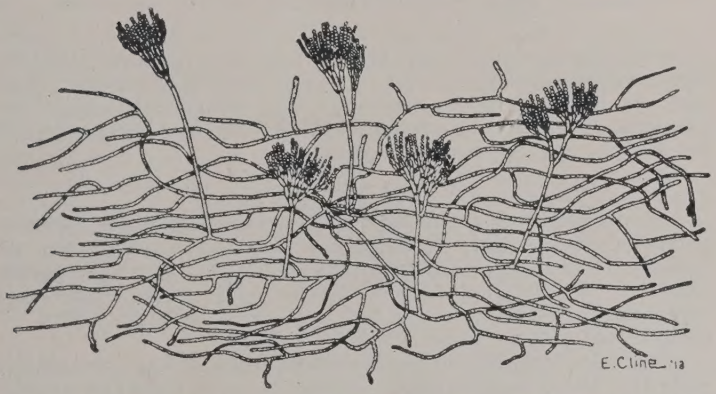

FIG. 1. A common fungus (mold) called blue mold (Penicillium), showing the fungous threads (mycelium) and the 1-celled spores (reproductive bodies). This mold often destroys apples and oranges in storage. Magnified 150 times.

to the naked eye, but in quantity they are visible as molds. A fungus living entirely upon dead organic matter is called a saprophyte, but when upon living tissues, it is called a parasite. There are all gradations between parasites and saprophytes, for a fungus may be parasitic for a while and then live for months as a saphrophyte, or the reverse condition may exist. Nearly all fungi reproduce by spores, which are very small. These spores correspond to the seeds of crop plants, and require favorable conditions of moisture and temperature for their germination and growth.

Bacteria are very much smaller than fungi. They are not thread-like, but spherical, or more or less elongated. They are the lowest form of plant life, and so small that single bacterium cannot be seen with a naked eye or a simple hand lens. Bacteria reproduce by dividing into two parts. This process of growth and division continues rapidly so that countless numbers soon form. Many bacteria are useful and harmless, but some cause diseases in plants, and others cause diseases in animals.

Viruses are unlike fungi and bacteria. The causes of virus diseases are not yet well known. However, there is some contagious substance in the juice of virus-diseased plants that causes the disease, and spreads it from diseased to healthy plants. Viruses cause many diseases of plants and of animals.

METHODS USED FOR CONTROLLING POTATO DISEASES

There are five important factors to be considered in a program for controlling diseases of potatoes; namely, seed selection, crop rotation, seed disinfection, spraying, and proper storage. More than one factor is usually associated with controlling a single disease, thus these factors must be considered not only independently, but also in their relation to each other.

Seed Selection

Seed selection is probably the most important single factor in potato disease control. Indirectly it is valuable in securing increased yields and uniformity in size, shape and quality of tubers. Selection of individual hills or tubers is the most reliable and satisfactory method, and the best way to accomplish this is by using a seed plot (p. 11).

The Montana Potato Improvement Association, cooperating with the Montana Extension Service, is now providing official inspection and certification of fields grown for seed.[1] The requirements for certification insure high quality in the product, and most of the certified seed has been so satisfactory that the market demand is usually good. The requirements for certification are practical, so that any careful grower can meet them and produce profitable yields of certified seed.

The potatoes from fields which fulfill the requirements for certification may be sold as certified seed under official tags, "Montana Certified Seed Potatoes," issued by the Montana Potato Improvement Association. "Certified Seed" usually commands a premium on the seed market in competition with common stock, as it has been inspected both in the field and in the bin by an authorized inspector, and it has been found to be practically free of all kinds of diseases and to be good in other respects as well.

Crop Rotation

Rotation of crops is an important factor in controlling potato diseases, because the causal fungi of many diseases over-winter in the refuse and decaying organic matter in the soil. Some of these fungi remain alive in the soil in the absence of potatoes for at least three years, so a five-year rotation has proved satisfactory under most conditions. Practice has demonstrated the advisability of adopting a system of crop rotation suitable to a locality, and following it as a definite plan.

The advantages of using high-quality seed that has been treated, in combination with crop rotation, cannot be overemphasized.

[1]Details regarding this service may be secured by addressing the Secretary, Montana Potato Improvement Association, Bozeman.

Seed Treatment

Introduction

Usually it is profitable to disinfect all tubers used for seed. Many disease-causing organisms present on the surface of the tubers are difficult to recognize when they are not abundant. Seed treatment will kill these surface-borne organisms and should always be practiced in a rotation system of cropping to lessen the chance of soil contamination. When potatoes are planted in infected soil, the value of seed treatment is decreased because the soil is then the main source of infection. Tubers should always be graded before treatment to eliminate cracked, bruised, and decaying tubers. To avoid injury, they should be treated while dormant and before cutting.

Disinfecting Materials

Several mercury compounds and formaldehyde may be used for disinfecting potato tubers. Potatoes treated with any mercury compound are poisonous and should never be used as human food or feed for livestock. Mercury compounds are generally more effective than formaldehyde for controlling rhizoctonia. Formaldehyde is more often used for controlling scab. It retains its strength with successive treatments, it does not have a corrosive action on metals, and usually costs less. Formaldehyde vapor, however, is irritating to the nose and throat, especially when it is used hot. Some form of mask, therefore, should be worn.

Treatments are made by soaking the seed tubers in a solution of the chemical, or dipping them in the suspension of some of the mercury compounds.

Formaldehyde

Hot Formaldehyde Solution.—This is a popular and efficient treatment for seed potatoes. It is effective against the causal organisms of disease which are surface-borne such as those causing scab, rhizoctonia, blackleg, and a few others.

For the hot formaldehyde treatment make a sufficient solution in the following proportions: 1 pint of 40 per cent formaldehyde in each 15 gallons of water. Heat the solution to a temperature of 124° to 126° F., and immerse the tubers (preferably in wire baskets or wooden crates) for 3 minutes in this hot solution. The correct temperature should be maintained, as, if the temperature is too high, it is injurious to the tubers while too low a temperature does not kill the parasite.

The advantages of this treatment are, efficiency in killing disease organisms, no injury to the seed, general availability, low cost, and adaptability for use on a large scale in tanks or in treating machines. The formaldehyde solution does not lose strength

with successive treatments. Its volume needs to be maintained from time to time by adding more solution of the proper strength, *i. e.*, 1 pint of 40 per cent formaldehyde in 15 gallons of water. Formaldehyde gas is not considered poisonous, but it is irritating.

After treating cover the tubers for 1 to 6 hours with a canvas or some old sacks which have been thoroughly disinfected (p. 9).

Cold Formaldehyde Solution.—Soak the tubers for 1½ to 2 hours in a solution made by adding 1 pint of 40 per cent formaldehyde to 30 gallons of water. After soaking, remove and cover the potatoes with treated sacks for at least 1 hour. If the tubers are treated in sacks, no additional covering is necessary. This treatment is recommended for scab, but is not so effective against rhizoctonia as the corrosive sublimate or hot formaldehyde solution. Wooden or metal containers may be used.

Mercury Compounds

Cold Corrosive Sublimate Solution.—The cold corrosive sublimate or mercuric chloride solution is prepared by adding 4 ounces of the chemical to 30 gallons of water. It is advisable to dissolve the chemical in a few quarts of hot water, and then add enough cold water to make 30 gallons. This quantity is sufficient to treat about 25 bushels of seed potatoes. Immerse the seed, preferably loose or in wooden crates, in the solution for 1½ to 2 hours. Do not use burlap sacks as containers in treating seed potatoes, as this chemical reacts with the sack material and thus weakens the treating solution. Tubers which have been treated should be planted immediately, or dried thoroughly before they are stored. To prevent reinfection of the treated tubers place them in new sacks, or old ones which have been disinfected for several hours in the corrosive sublimate solution or in a formaldehyde solution (p. 9).

The corrosive sublimate solution is gradually weakened during the process of treating successive lots of tubers. Its strength should be maintained by adding ½ ounce of corrosive sublimate dissolved in 1 quart of water after every 4 bushels of potatoes have been treated, and restoring its volume to the original level by adding some of the standard solution described above. Avoid treating very dirty potatoes, because the more dirt there is present the more rapidly the strength of the corrosive sublimate is reduced. Treat not more than 7 lots of potatoes, and then discard the solution. Special care should be given to the disposal of the discarded solution so that it will not be a source of danger to man, animal, or garden crops.

Caution.—Corrosive sublimate even in very dilute solution is a deadly poison if taken internally, but it is not injurious when applied externally to the surface of the skin. Do not use treated

tubers for feed because they are poisonous. As the name indicates, this solution corrodes metal, so only wooden or crockery containers should be used. Potatoes treated with any mercury compound are poisonous and should not be used as human food or feed for livestock.

Acid Mercury Dip Solution

This method has been used for several years, and the results obtained indicate that it has many advantages over the hot solutions or the long-time treatments.

1. Add 6 ounces of mercuric chloride to 1 quart of commercial hydrochloric acid (muriatic acid). It will dissolve immediately. This solution may be purchased already mixed.[1]
2. Measure 25 gallons of water into a wooden barrel, tub, or concrete tank. A metal container may be used if thoroughly painted inside with heavy asphaltum paint. The solution will corrode metal.
3. Pour the quart of acid containing the mercuric chloride into the water and mix thoroughly.
4. A wooden crate, or wire basket thoroughly painted with asphaltum paint, should be used for dipping the potatoes.
5. Dip the potatoes in the solution and allow them to remain for at least 5 minutes. If there is much scurf on the tubers they may be soaked longer. Soaking 40 minutes will not injure them.
6. It is better to treat the tubers before cutting.
7. Twenty-five gallons of the solution is enough to treat 40 or 50 bushels of potatoes, after which the solution is likely to be too weak. It can be brought back to approximately original strength by adding ½ pint of the stock solution and enough water to bring the solution back to 25 gallons. After 40 or 50 more bushels have been treated the solution should be discarded.
8. Unless the tubers are planted immediately, they must be spread out to dry. Do not store treated potatoes while they are wet. This is likely to injure them.
9. The diluted treating solution is not strong enough to injure the hands in ordinary practice. The strong acid should, however, be handled with care.
10. Remember that **Mercuric Chloride is a Poison.**

Hot Corrosive Sublimate Solution

Dissolve 2 ounces of corrosive sublimate in 15 gallons of water, heat to a temperature of 126° F., and immerse the tubers for 2 minutes. Remove the tubers, place them in new or disinfected sacks,

[1]The acid solution of mercuric chloride can be obtained in the market under the trade name "Mercurnol." One quart of this solution is added to 25 gallons of water and the material is ready to use.

and allow them to dry, or plant them immediately. These directions must be followed to secure good results and avoid injury to the tubers. This solution should be used in wooden or concrete vats. Do not feed treated tubers as they are poisonous.

Organic Mercury Compounds

Manufacturers have recently advocated some organic mercury compounds for either dust or dip treatment of potatoes. Although favorable results have been obtained in some tests with these compounds, it is necessary to prove their merit under different conditions before they can be recommended. They seem to have possibilities of giving beneficial results in the control of seed-borne diseases. Generally they are more expensive than the other treatments and are not superior to them. In using these compounds, the manufacturer's directions should be strictly followed.

Disinfectants for Cutting Knives, Sacks, Canvas, Etc.

Cutting Knife Disinfection.—In connection with potato seed preparation it is very important that the cutting knife be properly treated, otherwise certain diseases such as blackleg and ring rot may be spread through this agency. Self-propelling[1] or power driven[2] cutting knives with continuous disinfection have been described.

Mercuric Chloride.—This chemical is one of the best knife disinfectants, although it corrodes the knives slowly, making it necessary to replace them occasionally. The usual strength recommended is 1 part of mercuric chloride to 50 parts of water. Approximately 800 pounds of potatoes should be cut with each gallon of disinfecting solution, as it tends to lose strength due to its reaction with tissue debris, dirt, etc. Only relatively clean potatoes should be used, otherwise the disinfectant should be renewed more often, i. e., after every 500 pounds.

Acidulated Mercuric Chloride (p. 7) may be used in place of the ordinary mercuric chloride.

Iodine Solution[3].—The knife disinfectant recommended consists of iodine 38 grams, potassium iodide 76 grams, glycerine 1 pint, and water 2 gallons.

Other Solutions.—Many other solutions such as calcium hypochlorite, cresol compounds, etc., have been tested for knife disinfectants, with varying success, and it is possible that due to war conditions it will be difficult to secure mercuric chloride and that some of these, though not as efficient, will have to be substituted.

[1]Montana Agri. Exp. Sta. Cir. 161. Dec. 1940.
[2]Wyoming Agri. Exp. Bul. 244. Feb. 1941.
[3]Phytopathology 31:955-956. 1941.

Disinfecting Old Sacks or Canvas.—Sacks or canvas may be disinfected (1) by boiling in water for 30 minutes; (2) by dipping them in a solution consisting of 1 pint of formaldehyde in 15 gallons of water, and drying them rather slowly at a temperature not lower than 50° F. so as to allow the gas fumes to act for 1 hour or more; (3) by wetting them thoroughly in a solution consisting of 1 ounce of corrosive sublimate in 7½ gallons of water.

Suberization

Under certain conditions the cut surfaces or wounds on potato tubers become healed. This healing is essentially the formation of a protective layer of cells with thickened walls and the process is known as *suberization.*

Suberization is based principally upon three conditions, namely: the presence of sufficient air to furnish oxygen, high humidity (80 per cent or higher) and temperature between 60 and 70° F. If these conditions are furnished suberization will usually take place in approximately 48 hours.

To suberize freshly cut seed pieces put them in wet burlap sacks and place them in a protected building or shed and maintain proper conditions regarding humidity and temperature. If the sacks dry out too rapidly they should be sprinkled with water to maintain high humidity. In piling the sacks care should be taken to allow free circulation of air which is one of the factors favoring suberization.

Lack of proper suberization is probably the most important factor in seed-piece rot in the field, and is responsible for a considerable loss of tubers in storage.

Many tests have shown that suberization is much more effective in preventing seed-piece decay than treating the cut seed pieces with one of various fungicides such as land plaster, sulphur, etc.

Suberization of injured tubers before placing them in storage, and of cut seed pieces is an inexpensive and economical practice and should be more generally adopted.

Spraying to Control Diseases

Bordeaux Mixture.—In order to control the early blight disease, which has become destructive in some localities, spraying the foliage with Bordeaux mixture is advisable.

The materials for Bordeaux mixture are copper sulphate (bluestone or blue vitriol) 5 pounds, unslaked lime 5 pounds, and water 50 gallons. This is known as the 5-5-50 formula.

Preparation of Bordeaux Mixture.—Have three wooden barrels and two wooden pails. Put 25 gallons of water into one barrel. Dissolve 5 pounds of copper sulphate in this barrel by suspending

it over the water in a piece of coarse burlap with a portion of the chemical hanging a few inches under water. It will dissolve more quickly by this method than if thrown loosely in the bottom of the barrel. Start this a few hours before the solution is needed.

Slake 5 pounds of lime in the second barrel or in a pail. In slaking, add water a little at a time, and stir constantly. The lime should not be allowed to become dry, nor should it be submerged. After the slaking is complete, enough water should be added to make a total of 25 gallons. The lime should be strained through a sieve, 20 meshes to an inch, before mixing with the copper sulphate solution.

Chemical hydrated lime is satisfactory for the preparation of Bordeaux mixture, but use 7 pounds of this material in the formula if it is substituted for quicklime.

Pour into the third barrel, first a pailful of copper-sulphate solution, then a pailful of lime mixture, and so on. If two persons are working together they should pour the two liquids together into the third barrel.

The resulting mixture should be blue. A tinge of green indicates that it has not been properly mixed.

If it is impossible to spray immediately because of unfavorable conditions, add ¾ of an ounce (a heaping tablespoonful) of sugar dissolved in a little hot water to each 50 gallons of Bordeaux mixture. This will keep the spray mixture in good condition for several days. If the sugar is not added, Bordeaux mixture deteriorates very rapidly, becoming practically worthless if allowed to stand overnight. The best plan is to make it immediately before using.

Spraying potatoes requires from 75 to 125 gallons per acre, depending upon the size of the plants. A pressure of at least 100 pounds should be maintained while spraying.

Lime-Sulphur.—This insecticide is the most satisfactory for the control of psyllids, which cause "psyllid yellows" (p. 35). It is sold either in the liquid or dry form. Since liquid lime-sulphur may vary in concentration, its strength in degrees Baume should be known in order to make a spray of a definite concentration. The strength of the liquid lime-sulphur commonly sold in Montana is 28° Baume.

For spraying potatoes with lime-sulphur prepare a mixture of 1 gallon liquid lime-sulphur 28° Baume, or its equivalent, in 35 gallons of water. In using dry lime-sulphur add 1 pound to 8 gallons of water.

Other Sprays.—Spraying potatoes with arsenical compounds for controlling certain insects has been practiced for many years but a discussion of insect control is not within the scope of this bulletin.

Storage

Various rots of potato tubers cause considerable loss each year due to poor ventilation, high humidity, and unfavorable temperature. The best storage facilities for potato tubers are provided when the temperature is kept between 35° and 38° F., and the storage room is kept well ventilated Under these conditions the losses from tuber rots and other storage diseases will be reduced to a minimum. All lots of potatoes have more or less mechanical injury as a result of harvesting and placing in the cellar. Many of these injuries will heal or cork over in about two weeks, if the cellar temperature remains between 50° and 60° F., and if the humidity is high. After two weeks storage under these conditions the temperature should be reduced to around 37° F.

To kill the organisms that cause various diseases occurring in storage, the storage places should be thoroughly cleaned and disinfected each year before harvest time. For disinfecting, spray the storage place with either of the following solutions: 1 pound of copper sulphate in 10 gallons of water, or 1 pint of formaldehyde in 10 gallons of water. After spraying the house should be well aired and dried before it is used for storage.

Potato Seed Plot

Introduction.—The grower who desires to maintain or improve the vigor of his own seed stock should adopt the seed plot method for this purpose. The virus diseases of the potato are transmitted from one crop to the next in the tubers, and for this reason seed treatment will not control virus diseases. The only satisfactory known method for reducing virus diseases is by thorough field roguing of diseased plants, and by saving seed tubers from apparently healthy plants. This is most easily accomplished by the use of a seed plot, and the seed plot has been recommended by the Montana Agricultural Experiment Station for many years. This method, because of its importance, will be discussed in detail.

Object.—The object of the seed plot is to improve the seed.

Size.—To furnish sufficient seed, the seed plot should be about one-tenth as large as the acreage to be planted in the field the following year.

Location of Seed Plot.—This should be on ground which has not recently grown potatoes, but which is well adapted to growing them. It should be separated by at least 200 yards from other potato plantings to reduce the danger of insects carrying diseases from the general field to the seed plot. Aphids are the principal agents in transmitting virus diseases from plant to plant.

Seed.—Use high quality seed stock. Discard all tubers that show internal molds or rots, because moldy tubers produce weak plants. Careful inspection during cutting of the seed may reduce

trouble from blackleg (p. 23) and ring rot (p. 24). Treat all seed with either hot formaldehyde or corrosive sublimate solutions (pp. 5-7).

Planting.—Recent work has shown that there is a marked difference in the growth of potatoes from different sized seed pieces. All seed stock, therefore, should be cut so that the seed pieces will be about equal in size to promote uniform growth. The seed pieces from each tuber should be kept separately, thus facilitating planting by the tuber-unit method in which all seed pieces from a single tuber are planted adjacently in the row. A gap or space of about 18 inches between tuber units is advisable to mark the limits of each tuber-unit. Tuber-unit planting facilitates roguing, as degeneration diseases are more easily detected in units of plants than in an individual plant in a mass-planted field. Some growers in Montana have found that it is profitable to plant whole fields in tuber-units.

Care.—The seed plot should receive the best cultural care.

Roguing.—Roguing consists of pulling out all diseased, weak, abnormal, or otherwise undesirable plants with their seed pieces and tubers. It assumes the ability of the workman to detect varietal mixtures and diseases such as virus diseases, blackleg, fusarium wilt, rhizoctonia, and the like, in their various forms. The symptoms of most virus diseases from infected tubers are apparent within two months after planting. Roguing early in the season is therefore beneficial as it eliminates these plants which otherwise would be sources of infection. A seed plot should be rogued every ten days during the early part of the season. Later, the intervals may be lengthened as the judgment of the grower may indicate.

The symptoms of any one disease are most readily visible under certain conditions. For instance, mottling of leaves is more readily seen when the leaves are shaded, when they are not wet, and when they have not been recently sprayed with lead arsenate, Bordeaux mixture, etc. Plants affected with giant hill, bloom more profusely and are more resistant to light frost than are normal plants. Potatoes with degeneration disease often appear to be more susceptible to attacks by potato beetles.

In roguing, the plants with their seed pieces or tubers should be removed from the seed plot and burned or deeply buried. Placing the rogued plants, being careful not to shake off the aphids, in burlap sacks is a convenient and practical way to collect the plants before destroying them.

Spraying.—It may be necessary to spray the seed plot with Bordeaux mixture (p. 9) to protect the plants from early blight and tip burn. Potato beetles are controlled by applying lead arsenate, zinc arsenite, or Paris green. If aphids become numerous in a

seed plot they can be controlled by spraying the plants with a solution of nicotine sulphate. This spray is practical in a seed plot in which aphids threaten to spread virus disease seriously. (Detailed information regarding the control of insects affecting potatoes may be secured from the Entomology Department, Montana Agricultural Experiment Station, Bozeman.)

Improvement of Seed Stock.—To secure the best seed for the seed plot, stake the hills which show vigorous growth and the desired type of vine. Dig these by hand, and save for seed only those which have a high yield of tubers of uniform size and shape.

Digging.—The seed plot should be harvested under favorable climatic conditions, using special care in handling the crop to avoid injuring the tubers.

In an emergency when a disease like rugose mosaic is beginning to spread rapidly in a field, a seed stock may be saved by immediately harvesting the crop, even though the tubers are very immature. It is a valuable method only in so far as the tubers are dug before they are infected through the tops (p. 26), and should be practiced only in special cases.

Storage.—The seed stock should be stored in a well-ventilated storage room at a constant temperature of about 40° F. Danger of mixing seed stock with the field crop should be avoided.

The results from the seed plot method during the past few years have demonstrated that seed potatoes of high quality can be raised in Montana.

DISEASES CAUSED BY FUNGI

Rhizoctonia

Rhizoctonia is one of the most common and injurious potato diseases in Montana. It is the "dirt" that is difficult to remove from tubers.

Cause.—It is caused by a fungus, *Rhizoctonia solani*, Kuhn., which is quite widely distributed in soil and lives as a saprophyte on dead organic matter, including potato refuse.

Economic Importance of Hosts.—About 185 kinds of plants, including weeds, vegetables, ornamental plants, and field crops, have been listed as subject to attacks by this fungus. Some of the common plants in this list are potatoes, garden beets, sugar beets, carrots, asparagus, cabbage, cauliflower, alfalfa, red clover, and sweet clover. No cereal crop has been reported as affected by this fungus, so the use of cereals in a rotation is recommended.

Symptoms of Rhizoctonia.—The symptoms vary with the climate, soil, development of the host at the time of infection, and the virulence of the fungus. Several types of this disease will be described.

1. Black Scurf of Rhizoctonia.—Diseased tubers may be recognized by the superficial, irregularly shaped, elevated, dark-brown

or black patches of fungus threads (sclerotia, figure 2). These sclerotia vary in size from very small black dots to ¼ inch or more in diameter. The black specks are most easily seen when the tubers are wet, and it is usually at this time that they appear black. They are gray or dark brown when covered with soil. These sclerotia are masses of mycelium in a resting or dormant condition which carry the disease over winter. They are also the source of other types of this disease.

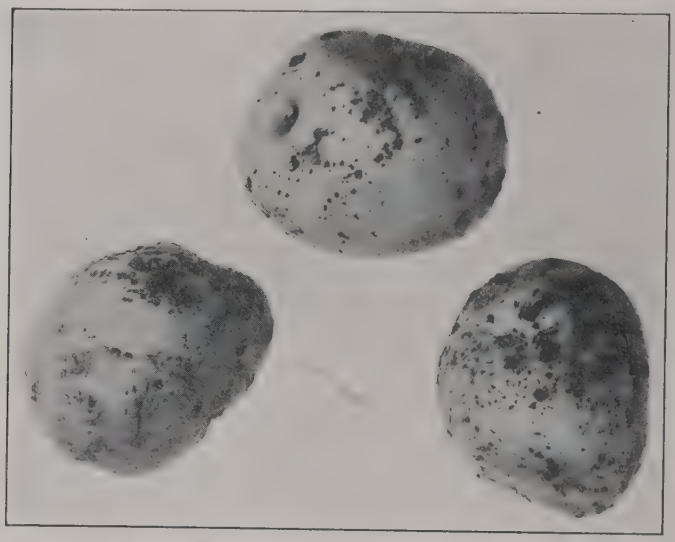

FIG. 2. Rhizoctonia on potato tubers, showing the "dirt that won't wash off." These are the overwintering bodies (sclerotia) of the fungus.

2. Rhizoctonia Pit.—This type of disease is believed to occur as a result of the penetration of the mycelium into the potato skin during the early stage of sclerotial development, or from a late growth of young mycelium from the old sclerotia. In severe cases these areas may form folds which rub off easily in the form of dust.

3. Rhizoctonia Tuber Rot.—This disease usually appears rather late in the season on elongated tubers grown under moist conditions when the fungus has become unusually virulent. It is not a common form.

4. Stem Lesions, Little Potato, and Leaf Rolling.—It is not always possible to distinguish these as separate forms of disease as the types of injury are often associated. A typical stem lesion

results from the penetration of the mycelium and the death of the invaded host cells. Leaf rolling, rosette, and little potato are secondary symptoms, and there is evidence that they represent responses of the plant to a disturbed condition of nutrition (figure 3). Similar effects are sometimes caused by purely physiological disturbances, such as breaking of vines, psyllid yellows, etc.

FIG. 3. Aerial tubers on a potato stem injured by Rhizoctonia.

The fungus also may attack the stem for a few inches above the surface of the ground. A dark network of fungus threads is sometimes seen upon the underground parts. This may advance above ground and develop a white to gray, spore-bearing layer on the base of the green stem.

Young potato sprouts when attacked by rhizoctonia may produce small, brown, sunken lesions or spots. These spots cause more or less injury, for in severe cases the sprouts are killed. New vines produced thereafter are often weak and late.

If diseased spots occur on the tuber-bearing stolons, or underground stems, the food supply may be cut off from the young tubers and only little potatoes may form. Sometimes they grow almost stemless in a cluster around the main stem. Little potatoes are evidence of underground injuries, and usually occur late in the season.

The fungus may cause lesions or spots ½ to 1½ inches long on the stem near the surface of the ground. These spots destroy the bark, and may cause the premature death of the stems. Stems which are severely injured but do not die, often produce aerial tubers and a few small underground tubers.

Tops of diseased plants usually have yellow to purple, crowded, upward rolled leaves with prominent veins. The stunted, discolored, rosetted plants resulting from severe injury by rhizoctonia are easily recognized in the field, but may be confused with psyllid yellows (p. 35).

Control.—Treat seed potatoes with mercuric chloride or hot formaldehyde as recommended (pp. 5-7). Adopt a five-year crop rotation and modern cultural methods. Although the rhizoctonia fungus occurs in many soils so that perfect control is rare, seed treatment and crop rotation usually enable the potato grower to produce commercially profitable crops.

Potato Scab

Potato scab occurs on all commercial varieties of potatoes and is familiar to all potato growers.

Cause.—Potato scab is caused by a fungus *Actinomyces scabies* (Thax.) Gussow. The organism may live for several years in the soil in the absence of a potato crop. Light sandy or sandy loam soils usually are more favorable for the development of potato scab than heavy soils. Practically neutral (pH 7.0) or slightly alkaline soils are favorable to the disease while potatoes grown on strongly acid (below pH 5.2) or strongly alkaline above (pH 8.0) usually have very little of the disease. Scab develops on potato tubers most readily at fairly high soil temperatures and low moisture content, although it sometimes occurs in soils with a high moisture content. When raw scabby tubers are fed to animals, the scab organism passes through the alimentary tracts of the animals and may be carried in the manure to uninfected soils.

Losses Caused by the Disease.—Potato scab causes an annual loss of several million dollars in the United States, due to the lowering of the market price of scabby potatoes. Clean, smooth potatoes, always command a higher price and a readier sale in a competitive market. For culinary use there is always much more waste with scabby potatoes sometimes amounting to 1/3 of the total weight of each potato. Scabby tubers are not desirable for seed, and they are more likely to decay in storage. Scab may reduce yields from 15 to 20 per cent.

Symptoms of Potato Scab.—The scab first appears as small reddish or brownish, slightly raised spots on the tubers. Under favorable conditions these spots enlarge, so that in severe cases the entire tuber may be covered with the diseased spots. Potato

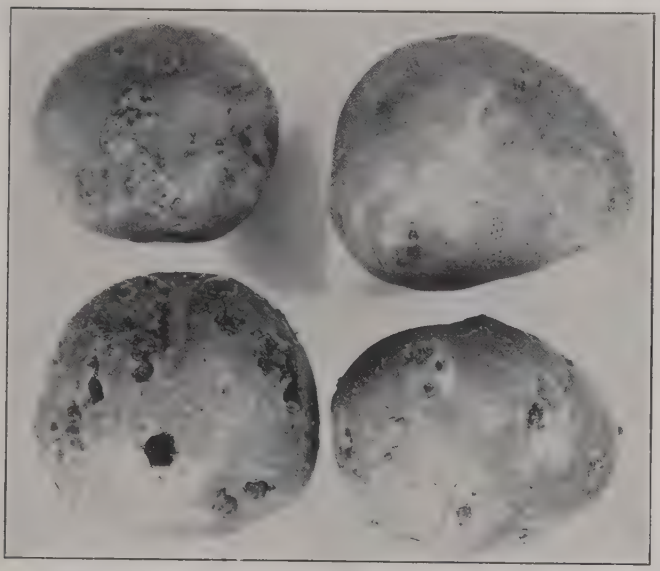

FIG. 4. Different types of potato scab. Upper left, common scab. Upper right, russet or superficial scab. Lower left, pit scab. Lower right, normal tuber.

scab lesions vary in type from superficial or russet, to common (corky type), to pit or even raised forms (figure 4).

Common potato scab should not be confused with powdery scab caused by *Spongospora subterranea* (Wallr.) T. Johnson which is rare in Montana. Powdery scab forms small blisters, or pustules which break through the skin. The skin curls back around the spot, exposing the brownish or dark green powder.

Eel worms, wire worms, etc., often cause a pitting of the tuber resembling scab, but close observation reveals the difference.

Control.—Scab is difficult to control and there is no single measure which will control it. The following practices are all of some benefit in a control program.

(1) Avoid the use of badly scabbed potatoes for seed.

(2) Treat seed potatoes with a seed disinfectant, preferably hot formaldehyde (p. 5).

(3) Avoid badly contaminated soils.

(4) Rotate crops so that potatoes will be planted in the same field only once every four or five years.

(5) In the rotation use grains, grasses, or legumes that are not susceptible to scab.

(6) Avoid the use of fresh manure just preceding the potato crop.

(7) If fertilizers are used, those that tend to make the soil more acid should be chosen, i. e., ammonium sulphate is preferable to sodium nitrate.

(8) Resistant varieties, if adapted to the locality, should be grown. The Netted Gem or Russet Burbank is quite resistant, while the Bliss Triumph and Early Ohio are quite susceptible to scab.

Early Blight

Early blight of potatoes is not very serious in Montana, although it occasionally causes damage around Billings, Chinook, and Hardin.

Cause.—Early blight is caused by a fungus called *Alternaria solani* (E. & M.) J. & G.

FIG. 5. Early blight caused by Alternaria.

Symptoms.—The leaves are usually attacked. Large spots with concentric rings or bull's-eye markings are formed on the leaves (figure 5). The vine is often killed by the disease if the infection is general and the spots are numerous.

Small, more or less circular spots are sometimes formed on the tubers. These spots are slightly sunken, and the margins of the diseased areas are somewhat raised. These spots are not very serious in themselves, but often serve as entrance points for rot-producing organisms. Early blight infection of tubers has not been observed in Montana.

Control.—The fungus lives over winter in the old plant refuse left in the field, from which it spreads in the spring. Such refuse should be destroyed.

Early blight on the leaves can be controlled by the use of Bordeaux mixture (p. 9). Begin spraying when the disease first appears, and continue at intervals of 10 days.

Fusarium Wilt

Cause.—Fusarium wilt is caused by several fungi of the genus Fusarium. The most important of these in Montana are *F. oxysporum* Schlecht. and *F. solani* (Mart.) App. & Wr. *v. eumartii* (Carp.) Wr.

The symptoms of these two diseases are quite different so each will be described.

Symptoms of Wilt Due to Fusarium oxysporum.—The distinct characteristics of the disease caused by *F. oxysporum* is a yellowing of the lower leaves followed by the rapid wilting of the entire potato plant, or, as often occurs, of individual stalks in a hill. The fungus may be present in the roots, stolons, tubers, and stem and is chiefly confined to the vascular bundles. Vascular discoloration in the stem usually does not extend above the surface of the ground. Internal discoloration of tubers is chiefly confined to vascular bundles and is of a light brown color (figures 6 and 7).

Symptoms of Wilt and Tuber Rot Caused by F. solani v. eumartii.—When a potato plant is infected with *F. solani v. eumartii* the youngest leaves show a yellowing of the areas between the veins, accompanied by necrosis of portions of these areas. This results in indefinite, small brown patches or so-called bronzing. In case of a severe attack, the leaves droop and hang to the stem as shreds of dry tissue. Complete wilting follows. Under moist conditions the infected plants may never show more than a slight yellow mottling and bronzing of the upper leaves, but the new tubers will show a very high percentage of stem-end rot and vascular discoloration. Roots, stolons, tubers and stems of diseased plants may show the presence of the fungus. A stem of a diseased potato plant shows a brown discoloration of vascular bundles and

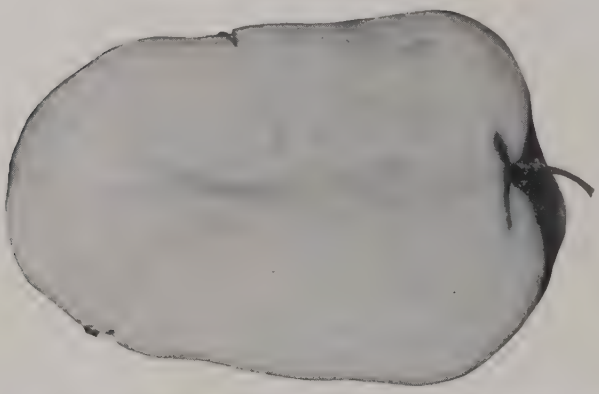

FIG. 6. Field wilt caused by Fusarium; stem end discoloration near surface of tuber a good indicator, when vines have typical symptoms.

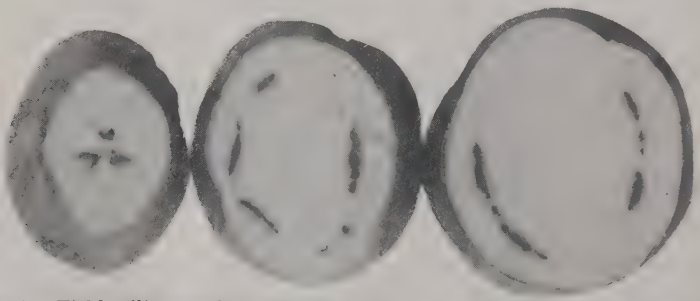

FIG. 7. Field wilt caused by Fusarium; tubers showing brown discoloration of vascular (water-conducting) rings.

necrosis of the pith and cortex. This discoloration extends into the upper part of the stem and foliage. The pith often shows discoloration at the nodes. Tubers usually show sunken areas at the stem-end and the internal discoloration is usually of various types, but chiefly of a vascular type and is often accompanied by a soft, watery, light brown discoloration of adjacent tissue about ¼ of an inch or even more in diameter.

The time of the appearance of the potato fusarium wilts varies according to the severity of infection, the age of the plants, and the variety. The plants usually show the first symptoms of the disease about blossoming time or earlier if infection takes place from affected seed tubers. Sometimes only one stalk may be

affected, but more commonly two, three, or all the stalks show symptoms. As a result of the partial killing of many of the roots, the wilted plants may be pulled out of the ground much more easily than healthy ones. Infection of potato plants in the soil is favored by a high moisture content, but after infection takes place wilt is accelerated in a soil with a low moisture content. The brown discoloration of the vascular ring of a potato tuber may also be due to the environment or to other diseases.

Control.—Healthy seed potatoes and crop rotation aid considerably in the control of these diseases. The most effective method of selecting seed stock free from wilt is by means of the seed plot (p. 11). Wilted plants and their tubers should be removed from the field. Growers should reject, for planting purposes, all lots of potatoes in which many tubers show ring discoloration. This symptom is readily seen by cutting off a thin section of the stem end of the tuber. In Nebraska it was found that early planting regularly resulted in the greatest amount of infection. Seed treatments alone will not control wilts.

Storage Dry Rot

Cause.—Storage dry rot is caused by several species of fungi called Fusarium, which are different from the Fusarium causing field wilt. The diseases are different although the causal fungi are closely related.

Losses.—Storage rot occurs wherever potatoes are stored. The annual loss from this disease is about 4 percent, but in severe cases it may exceed 50 per cent.

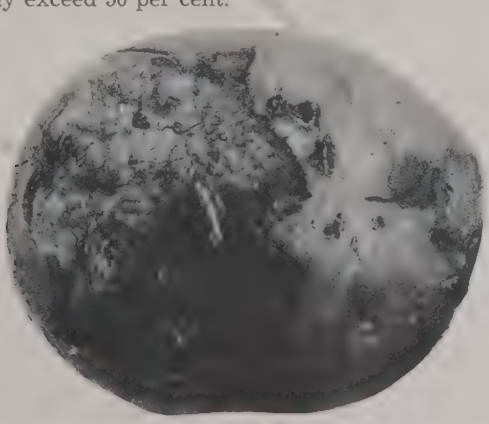

FIG. 8. Storage dry rot of a tuber. Sunken, brown region with white mold (Fusarium).

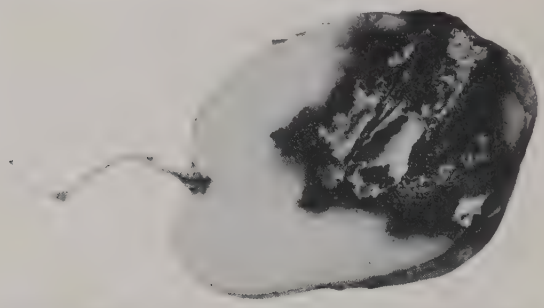

FIG. 9. Internal view of a tuber with dry rot, and the white mold (Fusarium) that causes it.

Symptoms.—The fungus usually attacks the tuber through breaks in the skin that are caused by rough handling of potatoes during harvesting and storing. The diseased portion of the tuber has a wrinkled, sunken appearance, and later may show cavities and tufts of the mycelium of the fungus (figures 8 and 9). The diseased tissues vary from nearly black to light brown and may be gray or nearly white, because of the mycelium and spores of the Fusarium fungus.

If the disease has progressed only slightly, a small sunken spot may be the only indication on the surface. With favorable conditions the rotting continues until the entire contents of the tuber become a dry, powdery mass of decomposed cells, starch grains, fungous mycelium and spores, leaving merely a cork layer (peel) on the outside.

Potatoes affected by this decay alone are never slimy and do not have a bad odor. If secondary rots occur, such as bacterial rots, there may be disagreeable odors and a wet rot of tubers.

In the common type of rot occuring in Montana, the fungus attacks the center of the tuber which decomposes rapidly, so that a very small spot on the outside may be underlain by a rotted region involving as much as three-fourths of the tuber. This disease does not attack growing plants in the field, but sometimes tubers are infected in the field before harvesting but after the vines have matured.

The causal fungus appears to live continuously in many soils. During the growing season, the tubers become contaminated (inoculated) on the surface but not internally. The spores also remain alive in the storage bins. When cut or broken tubers are stored, the fungus gains entrance through the wounds and destroys them, especially if the storage room is too warm and poorly ventilated.

Control.—The fungi causing dry rot are wound parasites, thus careful handling during harvesting and storing is recommended (p. 11). Grade carefully to eliminate all undesirable tubers before storing.

Losses will be slight when tubers are carefully graded and put in reasonably dry, well ventilated storage which is maintained at temperatures of 35° to 40° F.

It is a good plan to clean and disinfect storage houses with copper sulphate or formaldehyde (p. 11) before putting new crops into them.

DISEASES CAUSED BY BACTERIA

Blackleg

Blackleg is a bacterial disease of potato that occurs in Montana.

Cause.—Blackleg is caused by a bacterial organism, *Erwinia caratovora* (Jones) Com. S. A. B.

Symptoms.—The first symptom of the disease noticeable above ground is a wilting or yellowing of the lower leaves. Later, the upper leaves become yellow or reddish yellow and prominently upward rolled (figure 10). Black, somewhat sunken streaks occur on the lower parts of the stem near the surface of the ground. In extreme cases the black streaks extend to the upper parts of the stems, which often fall over. Cutting open the stems near the base reveals black pith. The tubers often develop a soft rot which usually starts at the stem end. Such tubers may rot entirely, or the disease may be checked at any stage. The disease is most destructive during warm, moist summers and autumns, so it often is not detected until the plants are half grown, or even later in the season.

There are at least three distinct sources of infection: (a) infected seed pieces; (b) infection of the seed piece by bacteria in the soil; and (c) infection following the attack of the seed pieces by the seed-corn maggot. The maggots pick up the bacteria from several possible sources, and introduce them into the wounds which they make by burrowing into the seed piece.

Control.—Because the diseased tuber is probably the main carrier of the disease over winter in Montana, no tubers having dark spots in the flesh should be planted. When a seed stock contains a small percentage of tubers showing the foregoing symptoms, disinfect with cold formaldehyde (p. 6), but treat after the tubers are cut, and for 1 to 5 minutes only.

The cutting knives passing through these diseased spots inoculate the cut surfaces of healthy tubers, and the organisms thus transmitted will be killed by this treatment.

A good practice is to rogue out all hills showing blackleg wherever they are detected. The diseased plants and their tubers should

FIG. 10. Potato stem dying from blackleg. The main stems are blackened, and the leaves are light green.

be removed and destroyed. Whenever a field shows a severe infestation of blackleg the crop should not be used for seed.

Ring Rot of Potato

Ring rot of potato, a bacterial disease which is caused by *Phytomonas sepedonica* (Spieckermann) Magrou, was found in Montana in 1939. This is a destructive seed-borne disease of potatoes

that has appeared in the principal potato growing sections of the United States since 1937. The disease was first reported from Maine and Canada in 1937 and in 1940 it had been reported from 39 states and Canada. It was found in six widely distributed counties in Montana and probably exists in some others.

Bacterial ring rot may cause wilting and death of individual branches or of the whole plant. Some plants may show very slight or no symptoms in the tops and still bear infected tubers. The first symptom noted is the wilting of a few leaves on the tip of a plant and later a mottling appears as the color fades to a pale green, then to a pale yellow. This wilting may progress until all leaves become wilted and the plant finally dies, or only one stem may be infected. The symptoms usually are manifested toward the end of the growing season, and unless careful observations are made the symptoms of ring rot may be confused with maturity, slight frost injury,leaf diseases, tip burn, etc.

Plants showing conspicuous symptoms of the disease usually bear some infected tubers. An infected hill of potatoes may contain some healthy tubers, some completely decayed tubers and varying stages in between. Often secondary organisms enter infected tubers and cause a complete decomposition of the entire tuber. The causal bacteria usually enters the tuber through the stolon, and tubers only slightly infected may show no external symptoms. Severely affected tubers may show some cracking of the skin, and a reddish-brown discoloration of the stolon end, and around the eyes.

The vascular tissues of an infected tuber are soft, cheesy-like in texture, and cream or yellow in color. The center of the tuber often decays leaving only a shell. Slightly infected tubers may often break down rapidly in transit or in storage causing considerable loss.

Control of ring rot is secured only by planting seed that is free of this disease. The disease does not appear to live over in the soil, nor spread in the field. Ring rot is very infectious, and for this reason, every precaution should be taken to prevent contamination of the cutting-knife, sacks, bins, planters, etc. Commercial growers should plant certified seed, or grow their seed in a seed plot (p. 11).

VIRUS DISEASES OF POTATOES

Introduction

Potato growers since 1775 have recognized "running out" diseases which greatly reduced the yield of their potato crop. Extensive research work since 1912 has shown that these diseases are caused by viruses (p. 3).

Virus diseases are very infectious and are spread by transferring the sap of a diseased plant to a healthy one. A virus once

introduced into a plant spreads to all parts of the plant and is transmitted to the next crop by means of the tubers. The most important known agents in spreading these diseases are the aphids (plant lice), which are often abundant in Montana in the potato fields during the latter part of the growing season.

The visible symptoms of the virus diseases are the abnormal shapes and color of the leaves as compared to a healthy plant. Other characteristic symptoms are dwarfing of the whole plant, stunting, rugosity, wrinkling, rolling and mottling of the foliage.

These diseases cause a reduction in size and number of the tubers, and in some cases the tubers are elongated, cracked and show internal discoloration. Tubers from diseased plants should not be used for seed.

At least 30 virus diseases on potatoes have been described, but some of these have since been proven to be the effect of a combination of two or more viruses affecting the same plant.

Control measures for virus diseases are discussed in detail under "General Practices Used in Disease Control" (p. 4). These consist mainly in the use of seed tubers from fields free or comparatively free of all virus diseases.

Only the more important virus diseases occurring in Montana will be discussed here.

Rugose Mosaic

Symptoms.—The most dependable symptom of rugose mosaic in vines from diseased tubers is the pronounced crinkling and rugosity of the leaves (figure 11). The mottling consists of very small and numerous spots of a lighter color than the normal green color of the healthy tissue. This mottling is easily seen during the cool weather of spring or fall, but often disappears after the temperature has been above 70° for a week. Potatoes having this disease in extreme form produce no tubers of commercial value.

Small brown spots 1/16 to ¼ inch in diameter often appear near the points of infection when aphids feed on potato plants affected with rugose mosaic and then feed on healthy plants. The veins on the underside of some leaflets often show disease areas as narrow black lines (figure 12). Brown to black streaks appear on the petioles of the leaves and on the stems and parts of the leaflets. Whole groups of compound leaves, and often whole stems die within a few weeks. Sometimes new leaves growing from the tops of the stems show mottling and wrinkling.

These current-season or primary symptoms are readily distinguished from injuries caused by frost, dry weather, cultivation and the like, with which they are sometimes confused.

Importance.—This is one of the most destructive of the virus diseases, because it is common and spreads very rapidly in the field.

FIG. 11. Rugose mosaic in Bliss Triumph potato (right) in comparison with normal plant (left). Diseased leaflets are dwarfed, mottled, ruffled, wrinkled, and curled. The lower leaves die and often drop. Stems are rigid and narrow.

Rugose mosaic results in a marked reduction both in size and yield of diseased plants. Affected plants die prematurely.

Crinkle Mosaic

The symptoms of crinkle mosaic are light color, ruffling and mottling of the leaves (see title page), dwarfing of the stems and considerable reduction in the yield of marketable tubers. The mottled spots are large and generally they are not apparent at high temperatures. Crinkle mosaic is less contagious and destructive than rugose mosaic. However, it is very common, and does considerable damage by reducing the yield as much as 50 per cent under some conditions.

Mild Mosaic

Potato plants affected with mild mosaic are often slightly dwarfed and have leaves that are mottled. Tests have shown that the yield of infected plants is only about two-thirds that of healthy plants. The symptoms of mild mosaic and crinkle mosaic are sometimes so similar that differentiation is very difficult.

FIG. 12. **A.** Normal leaflets. **B.** Leaflets mottled (light colored spots), ruffled, wrinkled and dwarfed by rugose mosaic. **C. D. E.** Leaflets showing current season infections with rugose mosaic. Lower sides of veins and midribs turned black or brown, and brown dead spots appeared. **F.** Normal leaflets.

Spindle Tuber

Potato vines showing distinct symptoms of spindle tuber are upright, dwarfed in height, and much narrower than normal vines. The stems are often more branched than usual, with the upper angles of the branches and stems abnormally acute (figure 13). In many cases the leaves are smaller and more pointed than normal. Affected tubers are dwarfed and are usually narrower and more spindle-shaped than normal ones (figure 14). The eyes are usually abnormally numerous. The tubers are often cracked. Many Bliss Triumph potatoes affected with spindle tuber are oblong instead of spherical, and may be light colored and cracked (figure 15). Spindle tuber in a mild form is very difficult to recognize and sometimes is confused with giant hill. Aphids and some other insects spread spindle tuber from diseased to healthy potatoes in fields.

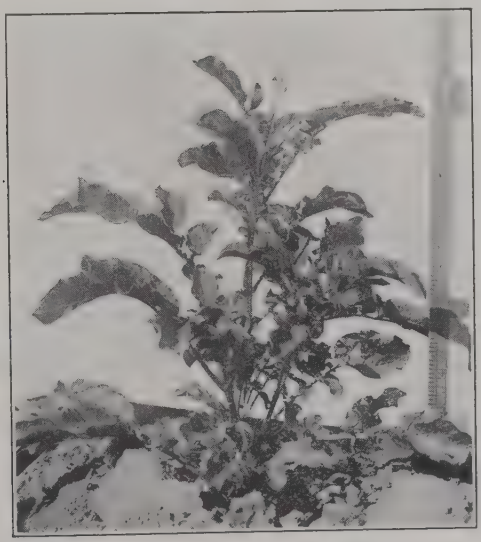

FIG. 13. Potato plants with spindle tuber, showing narrow upright type of growth.

FIG. 14. Netted Gem potatoes showing symptoms of spindle tuber. Note dwarfed, spindle-shaped and cracked tubers. N. Normal tuber. Two-thirds natural size.

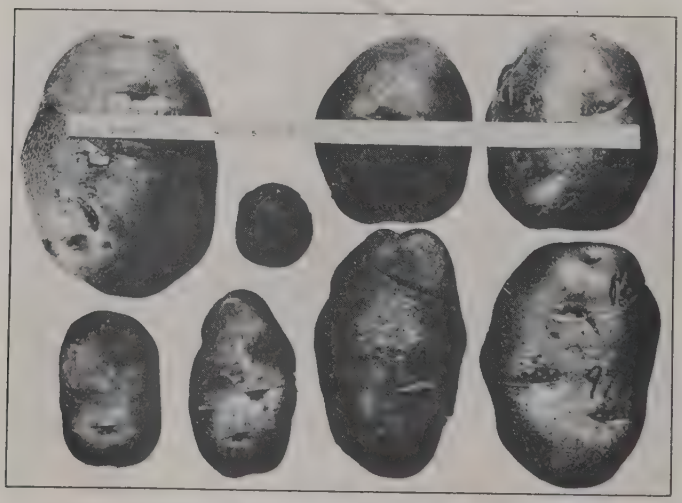

FIG. 15. Bliss Triumph potatoes, showing dwarfing, elongation, and too many eyes, as symptoms of spindle tuber.

Giant Hill

Giant-hill potatoes have abnormally large, coarse vines. They are most easily recognized near the end of the growing season because they bloom more abundantly, remain alive longer than normal plants, and are more resistant to frost and early blight. Giant-hill vines usually produce a fairly large yield of large tubers, some of which are rough, irregular, off-type, and cracked (figure 16). This abnormality is carried and spread by the tubers, but

FIG. 16. Bliss Triumph potatoes. Those marked "GH" are distorted and cracked, and show symptoms of giant hill. "N" means normal tubers.

is not known to be transmitted to healthy potatoes. Although it has not been proved to be a disease, producers of seed potatoes should remove giant-hill plants because they are badly off-type.

Leaf Roll

The leaf-roll disease causes the potato leaflets, especially the lower ones, to roll upward and become brittle, light colored, and dwarfed (figure 17). The internodes (parts of stems between the joints) are abnormally short. The vines are dwarfed, with short stems, and produce a rustle like paper when shaken gently. They bear small numbers of tubers on very short stolons. Spindling sprouts may grow from the eyes of such tubers when planted or stored. Rolling and brittleness of a few bottom leaves on large vines is often due to contact with hot soil in fields, but this symptom is too mild to be confused with leaf roll. Aphids spread leaf roll rapidly in the field. In plants affected late in the summer, the symptoms are rolling, brittleness, and light color in the top leaves. The older leaves on such plants appear to be normal. If the plants are infected just before they mature, the tubers may become diseased without the symptoms appearing in the tops. In such

Fig. 17. Burbank potato dwarfed by leaf roll, showing the prominently rolled leaves.

cases, the disease is not detected until the resulting vines show the leaf roll symptoms. This disease is not very common in Montana.

Witches' Broom

Symptoms in Vines Infected in the Field.—The current-season symptoms of witches' broom are very important. The tops of fairly large vines turn yellow, and yellow margins appear on many new leaflets. Later, aerial tubers often appear on the stems. The underground tubers may sprout prematurely, sending up many spindling little stems around the old vines. When such plants grow for a month or two after the symptoms have appeared, they usually produce from 40 to 200 very small tubers and a few large ones (figure 18). Witches' broom probably is carried to the succeeding crops mainly through these large, infected tubers, so plants showing these symptoms should be removed, with their tubers. This disease obviously spreads to healthy potatoes in the field, although the exact means has not yet been determined. It is easily transmitted by grafting together diseased and healthy stems or tubers.

FIG. 18. One hill of potatoes dug on September 25, 1915. The 184 tubers cover an area of only 25 square inches. The parent plant had witches' broom. (Printed originally in Jour. Agr. Res. **36**:835.)

Symptoms in Plants From Diseased Tubers.—Tubers having witches' broom produce many spindling little sprouts. Resulting plants are usually much dwarfed, with very small leaflets (figure 19). The leaflets often have yellow margins. Small tubers commonly occur on the stems. Such plants bear from 10 to 100 tubers apiece which are only 1/16 to 2 inches in diameter.

Importance.—In many potato fields in Montana, 5 per cent or more of the plants have been affected with this disease. Witches' broom reduces the yield of marketable potatoes from 10 to 50 per cent on vines with current-season symptoms, and vines from diseased tubers bear few or no marketable tubers.

FIG. 19. Witches' broom in a Bliss Triumph potato, showing numerous spindling stems with small leaves. One-third natural size.

Calico

Yellow to white blotches 1/16 to 2 inches wide in potato leaflets make the calico disease easily recognizable (figure 20). Potato vines are badly dwarfed when their leaves have many large calico blotches. Such vines produce much lower yields of marketable tubers than do normal vines. Consequently, potatoes with calico should be rogued.

Potato vines commonly are infected with both calico and mosaic, and thus show symptoms of both diseases. Irish Cobbler potatoes show a high degree of resistance or are perhaps immune to calico.

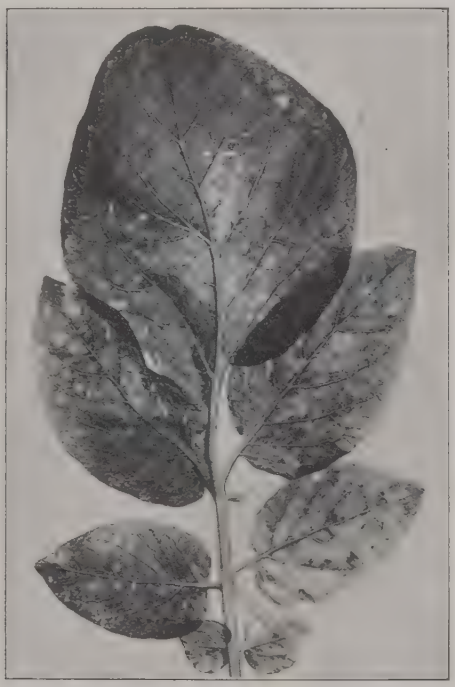

FIG. 20. Calico.

Spindling Sprout

Spindling sprout is not a separate disease. It is a symptom of witches' broom and of leaf roll. When diseased tubers are stored or planted, one or more slender sprouts grow from the eyes. Some physiological conditions, such as too warm storage, excessive sprouting and the like, also cause tubers to produce spindling sprouts. Such tubers should not be planted because they produce weak, often diseased vines (see p. 38).

PSYLLID YELLOWS—A POTATO DISEASE CAUSED BY AN INSECT (PSYLLID)

The first symptoms of psyllid yellows consist of a marginal yellowing and an upward rolling of the basal portion of the small leaflets on the young leaves of the infected plants. As the disease

progresses the rolling becomes more extensive, developing toward the tip, and the leaves become light green or yellow. In varieties such as Bliss Triumph and Irish Cobbler the rolled portions of the leaves become reddish or purplish in color. In advanced stages the yellowing becomes more prominent, brown necrotic areas develop, and the plant dies prematurely.

Buds below and above ground begin to grow. Many axillary buds on the vine grow into stocky buds that often branch, or they develop into aerial tubers. Many of the buds below the ground develop directly into new shoots or send out a cluster of new tubers at or near the soil surface. Several tubers may grow along a single stolon, giving a chain-tuber effect.

Psyllid yellows is caused by the nymphs (immature stages) of a sucking insect called the tomato psyllid (*Paratrioza cockerelli* Sulc.). This insect is commonly known as the jumping plant louse and is very tiny—about 1/12 inch long and not more than 1/24 inch wide. The nymphs are green while the adults are dark in color. The toxic substance injected by the nymphs into the plant results in abnormal physiology and form of the plant.

The effect of the psyllids on the plant is almost immediate and if a plant is attacked prior to tuber formation no crop is produced. If plants are attacked when older the crop is greatly reduced. Psyllid yellows is a serious disease only where the psyllid spreads and maintains itself. It does much damage in sections of Utah, Colorado, and Montana. The disease is not carried from year to year in the tubers.

The control of this disease is accomplished by controlling the psyllids by spraying with lime sulphur solution (p. 10). The potatoes should be sprayed when the plants are six to eight inches above ground. A second application should be made from two to three weeks after the first, depending upon the effectiveness of the first spraying as well as the weather conditions. The spray should be applied at high pressure (200 to 300 pounds) and the entire surface of the leaves thoroughly covered.

PHYSIOLOGICAL DISEASES AND OTHER INJURIES

Net Necrosis

This is a condition of the tuber in which there is a net-work of brown or black streaks in the flesh. It may be general throughout the tuber, or localized in the outer region, but shows no surface symptoms.

This condition may be a symptom of frost injury, fusarium wilt, leaf roll, or unfavorable environmental conditions during the growing season. Excessive heat in storage also causes discolorations in the tubers.

The presence of net necrosis makes the stock undesirable for culinary purposes, and reduces its marketable value. Affected tubers should not be used for seed.

FIG. 21A. Spindling sprouts of Bliss Triumph potato. Tuber germinated in laboratory. Longest sprout 8 inches long and 1/12 inch in diameter. (From same lot of tubers as 21B).

Spindling Sprout

The name is descriptive because it designates a condition in which long, slender, spindling sprouts are produced instead of normal, thick, vigorous ones (figure 21). Leaf roll and witches' broom are common causes of spindling sprout. Other factors which seem to induce it are adverse growing conditions just before harvest time, excessive sprouting, rotting of seed pieces, and storage or growth at too high temperatures.

Spindling sprout indicates a weakened vitality of the tuber. Such tubers because they produce weak plants should be rejected for seed stock (see p. 35).

FIG. 21B. Normal sprouts of Bliss Triumph potato. Tuber germinated in laboratory. Longest sprout 1½ inches long and ½ inch in diameter. (From same lot of tubers as 21A).

Tip Burn

This trouble usually prevails whenever hot, dry weather continues for a considerable period during late July or August. It affects the plant by reducing its leaf area.

The leaves turn brown and dry at the tips and margins. The affected areas become hard and brittle with a tendency to turn upward and inward. In severe cases, entire leaves may be affected. The oldest leaves and those on plants affected by some degeneration diseases are the most susceptible.

One form of tip burn is due largely to the loss of excessive amounts of water from the leaflets.

Another form of this trouble commonly called hopper burn is caused by a leaf hopper (*Empoasca fabre* Harris). It sucks the juice from the veins of the potato leaflets, but the exact manner in which it produces the disease is not known.

Tip burn is more prevalent in Montana than hopper burn.

Bliss Triumph, Early Ohio and Cobbler potatoes are susceptible to tip burn while Netted Gem is more resistant.

Control.—Keep the plants well supplied with moisture during hot, dry periods. Spraying with Bordeaux mixture at regular intervals is helpful in preventing this trouble. Begin spraying when tip burn first appears, and repeat the applications at intervals of ten days throughout the growing season. Bordeaux mixture also controls the leaf-hopper, killing many of the young and repelling the adults.

Frost Injury

Discoloration of the flesh of tubers often results when potatoes are exposed to low temperatures, commonly referred to as a light freeze. The average freezing point of potatoes is about 29° F., but this may vary a few degrees, depending upon the variety, previous storage conditions, type of container, duration of exposure, and the like. Under ordinary conditions 29° F. should be considered the danger point in exposing potatoes to low temperature.

Tuber discolorations due to low temperature may appear as: (1) a faint ring necrosis; (2) a ring necrosis in combination with net necrosis of the flesh; (3) blotches near the surface. (4) Under moderate freezing all discoloration disappears and soft potatoes will result with a sour odor and flabby texture. (5) Under severe freezing the "leaker" stage results. In this stage the sap escapes from the potato as soon as it thaws out, but no discoloration of the flesh results.

Control.—Potatoes should not be exposed to temperatures of 29° F., or colder. Ridging helps to prevent frost injury in the field.

Hollow Heart

This name is very descriptive as it applies to potato tubers with irregularly shaped white to brown cavities in their centers. This abnormal condition is confined mainly to large or oversized tubers, and is probably the result of too rapid development during the growing season. Decay is not associated with the cavity except when rotting fungi or bacteria enter from the outside.

The losses consist mainly in a reduced market value, and waste in the culinary processes.

The only known method of control is to follow cultural practices which will tend to reduce the number of oversized tubers.

Black Heart

Black heart is caused by overheating or poor ventilation of tubers. The symptoms are large black regions or cavities lined with black tissue, in the center of the tuber. These cavities are sometimes white until they are exposed to the air.

This condition is usually found in potatoes which have been overheated in transit, or stored under unfavorable conditions. Black heart has been produced artificially by exposing tubers to temperatures of 100° to 113° F., for 12 to 18 hours, or keeping them under poorly ventilated conditions.

The remedy is proper storage and avoidance of overheating in transit.

Tuber Formation in Dark Storage

Potatoes stored in a dark place at 40° to 70° F. for 8 months or longer, often produce new tubers (0.1 to 2 inches in diameter) on the ends of sprouts from the eyes. The sprouts may be a few inches long, or inconspicuously short. The sprouts and tubers are small and numerous on tubers stored in darkness for a year at 30° to 40° F. Some tubers naturally produce stems and new tubers, even under these abnormal conditions. Planted tubers without aerial stems sometimes produce such new tubers. Occasionally, new tubers are produced inside the old tubers. To prevent the formation of secondary tubers place them in storage that will prevent sprouting (p. 11).

Sunburn

Whenever tubers are exposed to sunlight or even to a strong diffused light for many hours, they develop a green or red color, due to the formation of chlorophyll, which gives the green color to leaves. Greened potatoes are objectionable for culinary purposes because they are bitter, and may be poisonous to some people. Greening does not injure the tuber for seed.

To prevent this condition keep potatoes well-hilled in the field and store the tubers in the dark. The color will usually disappear from green potatoes after they are stored in darkness for several weeks, unless the greening is very pronounced.

Enlarged Lenticels

Inquiries are often received regarding the white specks on tubers that grew in wet soil, or that have been stored where the humidity was very high. These white specks are lenticels or

breathing pores, which are usually inconspicuous, but become greatly enlarged when the tubers are kept under very moist conditions. On dry tubers the lenticels appear as small brown specks. Enlarged lenticels do not injure the tubers.

Quack Grass Injury

When quack and some other grasses are allowed to grow in a potato field, their root stocks will sometimes pierce the potato tubers. This is a purely mechanical injury, but is often quite a curiosity. The wounds affect the market value of the tubers.